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Experience and Reflection on Cultivating Graduate Students' Innovative Ability in the Course Teaching of Group Theory

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***Abstract*—The cultivation of innovative ability is the core goal of postgraduate education and the course teaching is very important for the realization of this goal. This paper summarizes and reflects on the construction process of high-quality graduate course of group theory in physics of Shandong Province, then probes into the teaching methods and content organization of graduate degree courses of science and technology, and especially emphasizes how to strengthen the cultivation of innovative and scientific thinking for postgraduate students in the course teaching.**

Keywords—group theory; graduate education; course construction; innovative ability cultivation

I. INTRODUCTION

As we all know, the postgraduate education department is at the top of the whole national education system. To a certain extent, the innovative ability of postgraduates affects the development of science and technology in the country. Therefore, it is very important to improve the quality of cultivating the innovative ability of postgraduates. Postgraduate stage is a period in which students' innovative thinking and ability are relatively active. In the education and teaching work, teachers should grasp the key factor of cultivating innovative ability [1]. As a necessary link in the process of postgraduate training, curriculum teaching must also focus on the cultivation of postgraduate's scientific research ability. The primary task of curriculum teaching is to lay a solid knowledge foundation for postgraduates. Knowledge is the foundation and precondition of scientific research innovation ability. Postgraduates should master two kinds of knowledge in course teaching activities: one is basic knowledge, and the other is frontier knowledge of the subject. In the course of teaching, the two kinds of knowledge should be imparted roughly with a clear division of labor: basic courses focus on the foundation, professional courses focus on the frontier. Although the teaching of basic courses need not emphasize the frontier of knowledge excessively, with the rapid development of society and science and technology, today's frontier of disciplines may be transformed into the basic knowledge of disciplines tomorrow. Therefore, basic courses must also keep pace with the times to enrich and update teaching contents, so as to adjust curriculum settings [2].

Course teaching is an important link affecting graduate students' innovative ability, and different teaching modes directly affect the effect of course teaching. Therefore, in order to cultivate postgraduates' scientific research ability and improve their innovative consciousness in an all-round way, it is necessary to explore appropriate teaching methods and modes for different disciplines and curricula, and to promote the reform and innovation of postgraduate teaching modes while effectively integrating traditional teaching methods. Due to the differences in teaching purposes and tasks of different courses, there should be differences in teaching methods, which can not be generalized. Taking the course of "Group Theory in Physics" as an example, combining with the current situation of graduate students' scientific research ability in local universities and colleges, this paper explores how to use classroom teaching to cultivate graduate students' innovative research ability.

Group theory is a basic degree course for first-year master of physics. It is an abstract mathematics and one of the basic mathematical tools that the students of physics and related majors must master in scientific research. At the same time, group theory is also a practical science, which has a wide range of applications in various fields of physics. Group theory describes and studies symmetry in nature, which can be geometric symmetry, system or equation symmetry, physical space-time symmetry, etc. Symmetry determines the commonness or universality of the system, and the properties of materials, systems and space-time in a large scale. In contrast with pure mathematical orientation, group theory in physics pays more attention to its specific application in research. Nevertheless, the innate characteristics of group theory, which lay particular stress on theory and tedious derivation, make students feel dull and boring, even in a low learning state. Most students have erroneous understandings such as "little use" and "no practicability". Therefore, group theory is generally recognized as "difficult to learn and difficult to teach" by teachers and students, and the overall teaching effect is relatively unsatisfactory, which is also a problem faced by other science and engineering theoretical courses [3]. In order to improve students' autonomous learning ability, stimulate their innovative spirit and research ability, the

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author's course team actively absorbs the relevant teaching reform experience of other colleges and universities. Starting from the characteristics of theoretical courses and combining with their own reality, teachers have explored teaching models with their own characteristics, and carried out systematic reforms in teaching concepts, teaching methods and means, teaching content and textbook construction. After several years of practice, some good results have been achieved. The following article will summarize and reflect on the work done by the course team, aiming at providing an effective and feasible solution for improving the quality of postgraduate training and cultivating innovative postgraduates in the course of teaching, and providing some reference for similar courses.

II. IMPROVING TEACHING SYLLABUS WITH THE TIMES AND GUIDING TEACHING WITH NEW IDEAS

Syllabus is a normative guidance document and a basis for teaching. The course team has formulated the general goal of the teaching reform of group theory, which is to strengthen the basic theory, keep up with the frontier of the subject, widen students' scope of knowledge, optimize the curriculum system, reform the teaching means and methods, enhance the cultivation of innovative ability and comprehensive quality, and finally achieve the goal of improving the quality of education in an all-round way. According to this goal, on the basis of summing up the long-term teaching experience of group theory, according to the teaching effect and students' feedback, the course teachers revise the syllabus with the times, so as to make it have the following distinct characteristics: 1) clearly putting forward the teaching goal of training students' comprehensive quality and ability to meet the needs of future work and scientific research; 2) increasing the practice teaching to enhance students' ability to integrate theory with practice; 3) the curriculum requirements are specific and appropriate according the discipline practice of the major; 4) the teaching content design is scientific and novel, suitable for the education characteristics of students in the new era.

The syllabus reflects our teaching idea and orientation of "three combinations": teaching and learning, teaching and research, theory and practice, besides student-centered teaching according to aptitude, rational use of various means to promote personalized and inquiry-oriented education, and attaching importance to cultivate students' abilities of physical thinking, independent learning, research and innovation.

III. REFORMING CURRICULUM SYSTEM AND UPDATING TEACHING CONTENTS

The course team actively promotes the innovation of curriculum system and teaching content, extensively absorbs, introduces and draws lessons from excellent teaching materials and resources of group theory at home and abroad, including first-class international academic journal literature, teaching courseware and software, etc., and forms its own characteristic teaching content. It highlights the practicability of content, the participation of students in methods, the guidance of teachers in teaching and the practicality of students in effect. Teachers can not only take students as the main bodies, but also pay attention to individual differences, teach students in accordance with their aptitude, so that students' personality can be fully developed. Specific practices are as follows.

A. *Modularization of Course Content According to the Relevance and Logicality of Knowledge Points*

The course of group theory is rich in content and has different emphasis on specialties. Therefore, the teaching of this course is based on students' basic knowledge, takes into account the needs of theoretical physics and condensed matter specialty, and strives to enable students to successfully establish a comprehensive knowledge system in limited school hours. In the course of teaching, teachers can simplify some traditional contents, but should aim at training research-oriented talents and not reduce the theoretical level. Based on the above facts, we divide the course content of group theory into three modules, and the corresponding knowledge structure is progressively advancing. Module-1 sets up the basic knowledge of group, Module-2 explains the representation of group, and Module-3 specifies the relationship between group and various symmetries. Each module is composed of knowledge points, basic content, expanded content (extracurricular practice, frontier lectures, etc.). Group theory is widely used in all fields of physics and related disciplines. According to the progress of teaching, teachers can choose several newly published academic papers on applying group theory to solve problems as lectures, so as to enhance students' interest in learning group theory and preliminarily understand the practical value of group theory. At the same time, we can guide students to carry out discussions on some practical problems, arrange course papers for practical training, and improve the practical application ability of knowledge.

B. *Combining the Teaching of Basic Theory with the Frontier and Supplementing Relevant Presentations*

One of the most fundamental and effective ways to carry out innovative education and optimize classroom teaching is to fully stimulate students' interest in learning. The reform of teaching content is based on the problems reflected in the long-term teaching process, and achieves the following points: 1) the cutting-edge knowledge is combined with basic theory and the teaching content is scientific and innovative. While teaching classical content, teachers constantly enrich the latest achievements of scientific and technological development, and pay attention to reflecting the characteristics of contemporary discipline development and the knowledge intersection and infiltration among different disciplines into the teaching content. 2) Paying attention to teaching scientific thinking methods, and laying the foundation for students to explore new things and improve their innovative ability. Teachers select the work of master of physics to show students the tortuous process of scientific exploration and the only way to solve the problems, i.e., the research process is mainly based on asking questions, catching the key points, overcoming difficulties, finding connections and revealing the essence. 3) Attaching importance to the link of theory and experiment or practice, and the combination of basic theory training with scientific research practice training. The core of scientific quality education is to cultivate students' practical ability and innovative spirit. The organic combination of practical teaching and theoretical teaching, which are relatively independent

teaching systems, is the focus of current teaching reform and the inevitable requirement of the times. In daily teaching, teachers always encourage students to actively apply their knowledge to participate in the research of teachers' scientific research projects. 4) Paying attention to the cultivation of comprehensive quality and ability to meet the needs of future social development and scientific research. In the organization of teaching content, the course team not only adds the content of new development of science and technology, but also designs appropriate training topics to improve students' ability to analyze and solve problems in practice.

IV. UPDATING TEACHING METHODS AND METHODS TO IMPROVE TEACHING EFFICIENCY

In order to adapt to the characteristics of students in the new era and the situation of teaching reform, combined with the characteristics of group theory, the course team actively studied and introduced new teaching methods and methods into teaching. Say concretely, teachers do well in teaching guidance for each class and each knowledge point, pay attention to the explanations of physical image and memory rule of physical formula, actively promote lively and orderly interactive teaching, reasonably interpolate the use of inquiry-based, discussion-based, interactive, thematic and other teaching methods, and widely carry out classroom discussion and exploration [3].

In addition, teachers are closely linked to the characteristics of the times and adopt various information technologies to guide students' interest in learning. We collect and organize students to elaborate courseware and software related to the course contents such as the demonstration of symmetrical operation, update and improve it repeatedly in use, in order to achieve excellent pictures and their accompanying essays to help students correctly establish physical images and cognition process. At the same time, the course website and QQ group have been set up in time, which provides students with rich content, including syllabus, teaching plan, courseware, domestic and foreign reference books, thematic papers, online question answering, etc. Students can not only review the content of the lesson, but also learn to expand knowledge and interact with teachers on the Internet in a timely manner, which greatly expands the space of students' autonomous learning.

V. COMBINING TEACHING WITH LEARNING, RESEARCH AND PRACTICE

The core of scientific quality education is to cultivate students' practical ability and innovative spirit. As a pure theoretical course, the traditional group theory teaching does not include practical and experimental teaching contents except after-class exercises. But nowadays, the modern educational concept has changed from knowledge-based and intelligence-based education to comprehensive quality-oriented education and emphasizing the cultivation of innovative ability. Practical teaching is becoming more and more important for the formation of the mastery and application abilities of courses [4]. Therefore, it must be introduced and strengthened. The course team provides students with more perfect practical teaching conditions for training and improving their scientific research quality and innovation ability. The hardware conditions include that the course team has a dedicated teaching and practical activity room equipped with multiple computers with Internet connected, which can better meet the requirements of practical teaching. In the process of practical training, all students adopt the mode of "one person one machine with class teacher tutoring". It not only effectively exercises the students' ability to solve problems by themselves, but also further consolidates the teaching effect. The school where the course team is located has six scientific research teams and their laboratories. If the content of students' practice is related to one of them, they can enter the laboratory to carry out relevant practical teaching activities as long as they make an appointment with the teachers in charge of each laboratory. In addition, in order to strengthen practical teaching, the course team has hired two senior scholars from high-level universities to give personal guidance and three young teachers as assistants. Students benefit greatly from their communication with the teachers. The above measures have greatly improved the depth, Frontiers and international perspectives of the course. Every year, the school vigorously carries out a series of scientific and technological practice activities, such as graduate innovation projects. Students are free to apply for various scientific and technological innovation projects, and the school provides financial support.

According to the characteristics of the course, the course team actively carries out practical training activities. The practical contents offered by the course team for students mainly include the front-line lectures of experts and the small topics, essays and speeches during the semester. Group theory has been widely used in various fields of physics and related disciplines. The course team actively cooperates with external experts and tutors to create a "science and technology forum". Teachers guide students to read extra-curricular literature and understand the development of subjects, and lead students to practice training, write essays, and encourage students to question and discuss boldly. At the beginning of every semester, the instructor will publish practical contents such as small topics and course papers, and then guide students to study literature to understand the application and development of group theory in various fields, train them to make comprehensive use of group theory and other physical knowledge and encourage them to try to solve theoretical problems and facts within their abilities. For high-quality course papers of students, teachers will instruct the corresponding authors to apply school-related projects, or collate and publish them as academic papers. Teachers will mark students according to their working attitude, workload and quality in practical learning, and take into account the normal course results as part of the final course results.

The above activities have greatly broadened students' horizons, deepened their understanding of basic knowledge, stimulated their interest in problems, fostered their scientific thinking and research ability, and laid a foundation for future work and further study, which has been fully praised and responded positively by all previous students. They have reflected that "getting practice outside of theory, deepening the understanding of theory and improving the ability to think and solve problems".

VI. Reforming performance appraisal methods and improving the system of course evaluation

The content of group theory is very theoretical. In the past examinations, only the students' grasp of relevant knowledge points was emphasized, while the students' comprehensive ability evaluation was neglected. The results show that although most students have a good grasp of theoretical knowledge, the ability and level of solving problems by using knowledge analysis are poor [5]. In order to change this situation and comprehensively test and evaluate the learning process and effect of graduate students, teachers constructs a scientific, feasible, objective and oriented teaching quality evaluation system through the following points: 1) the teachers correct all students' homework carefully, evaluate the results of each assignment, and regard it as an important part of the final grade. 2) Gradually reform the examination questions and transfer them from paying attention to the memory to the understanding and application of basic theoretical knowledge, so as to enhance the flexibility of the examination questions. 3) The usual performance is flexible with paying attention to practical teaching and including course papers, problem inquiries and academic reports, so that every student can experience the satisfaction of learning as far as possible. The above measures preliminarily solved the problems of single examination form and neglecting the evaluation of students' comprehensive ability.

VII. Summary

Generally speaking, the teaching reform of group theory course team in charge of the author has distinct characteristics, especially in three aspects: 1) the teachers skillfully combine a pure theoretical course with practical teaching, open a kind of fresh class forums, specially hire high-level experts from other universities to guide students' practical training, and obtain a lot of training results. Students also benefit greatly, and the scope of the course is broad and high. 2) In terms of teaching methods, the teaching team of group theory emphasizes the cultivation of graduate students' autonomous learning and scientific research ability, and carries out various methods, such as inquiry, discussion and interaction, to give full play to students' subjective initiative, which greatly stimulates students' desire for learning and has achieved remarkable results. 3) The contents of the course have always keep professional attitude, reflect the latest research results in the field of disciplines in a timely manner, and lay emphasis on the combination of explanations with the frontier issues of disciplines, which fully reflects the new requirements of the development of the times for talent training.

As a basic link in postgraduate training, course teaching should not only be the main channel for postgraduates to master basic theory and professional knowledge, but also the main place for teachers to impart the ideas and methods and share the experience of scientific research [6]. It should also be the key link and important way to cultivate the innovative spirit of postgraduates. The teaching reform of postgraduate course is a long way to go. At present, we are still exploring in combination with the teaching practice and learning from the experience at home and abroad.

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